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ABSTRACT

This paper presents a method for calculating the value of price risk reduction to a consumer that can be achieved with investments in energy efficiency. The examples presented deal with buildings and electricity for heating, but the principles can be applied to other contexts. The value of price risk reduction is largely overlooked so far in literature concerning the costs and benefits of energy efficiency in buildings. The topic is discussed to some length but in the literature reviewed for this paper no methodology for calculating the value was presented. Here we suggest such a method.

The problem of valuating price risk reduction is approached using a variation of the Black–Scholes model by considering a hypothetical financial instrument that a consumer would purchase to insure herself against unexpected price hikes. A rational consumer is prepared for a certain amount of growth in energy prices. If, however, the energy price rises more than expected, it might be very undesirable for the consumer. The consumer could, at least in theory, prepare for the unexpected rise by buying a cap contract on energy prices which would provide compensation for that unexpected rise.

Case examples calculated for typical single family houses in Finland are presented. The calculations concentrate on heating energy only, because there it is relatively easy to find examples of investments that reduce energy consumption, making it well-suited for demonstrating the issues at hand. Moreover, they concentrate on electricity as an energy carrier, as volatility data are needed and such data are available from the relatively well functioning electricity market in the Nordic countries.

The results show that the price risk entailed in household energy consumption can be reduced by a meaningful amount with energy efficiency investments, and that the monetary value of this reduction can be calculated using a variation of the Black–Scholes method. It is argued that this often overlooked benefit of energy efficiency investments merits more consideration in future studies.

1. INTRODUCTION

This paper presents a work in progress for developing a method for calculating the value of price risk reduction that can be achieved with investments in energy efficiency by an energy consumer. The main aim of this paper is to show how such a calculation could be done, while the optimal methodology is still being developed. The value of price risk reduction is largely overlooked so far in literature concerning the costs and benefits of energy efficiency in buildings. The topic is discussed to some length but in the literature reviewed for this paper no methodology for calculating the value was presented. Here we suggest such a method with some preliminary results from case examples.

The calculation examples presented in this paper deal with buildings and electricity for heating, but the principles can as well be applied to other contexts. The calculations presented concentrate on heating energy only because there it is relatively easy to find examples of investments that reduce energy consumption, making it well-suited for demonstrating the issues at hand. Moreover, they concentrate on electricity as an energy carrier, as volatility data is needed and there is a relatively well functioning electricity market in the Nordic countries.

In the literature there is a considerable amount discussion about an energy efficiency gap, meaning underinvestment in energy efficiency due to reasons that are not entirely clear. By this it is meant that there are apparently profitable investment opportunities that are nevertheless not taken by the various decision makers. Possible reasons offered range from information problems to liquidity constraints to misplaced incentives among others. Extensive reviews of the topic have been published by Gillingham et al. (2009), Brown (2004) and Klemick and Wolverton (2004) among others. Moreover, various authors (e.g. Abadie et al., 2013; Jackson, 2010) include the consumers' aversion of risky returns as one possible explanation of the energy efficiency gap.

From the economic point of view investment decisions concerning energy efficiency are evaluated according to the same principles as any other investments: the investment should be made when benefits are greater than costs. In this context savings in energy costs are the equivalent of a cash flow, to which the investment cost is compared. Or, as Gillingham et al. (2009) put it, higher initial capital costs are traded for lower but uncertain future energy operating costs. The uncertainty of operating costs is due to the price of energy which, being in future, is of course unknown.

In practice, according to Jackson (2010), those making the investment decisions do tend to take into account the risk of changing costs when making the decision but, rather than quantifying the risk, they opt to demand a short payback period to safeguard a quick profit. Jackson sees this leading into high-risk but likely profitable energy efficiency investments being overlooked and contributing to the energy efficiency gap.

To tackle the uncertainty of various cost components in energy efficiency investments, Abadie et al. (2013) offer a real options approach to produce a trigger investment cost to help decision making. Taking a similar approach, Jackson (2010) suggests a method for calculating confidence levels for various outcomes based on Monte Carlo simulations of relevant parameters. Vine et al. (2000), on the other hand, interestingly list a number of risk reduction opportunities related to energy efficiency investments and recognize the insurance value of these, but they do not include among them the topic of this paper, price risk reduction.

Thompson (1997) has recognized the reduction of price risk provided by energy efficiency investments and suggests tweaking discount rates in the investment calculation to take it into account. While he gives a sound argument for doing so, he does not provide a method for deciding what the discount rate should be, i.e. what is the value of the reduced risk.

This paper suggests a novel approach to provide a monetary value to the reduction of price risk with energy efficiency investments. This will allow decision makers to compare the value of risk reduction to other cash flows of the investment. Presently the value of reduced price risk, while widely recognized in the literature, is commonly excluded from investment calculations.

1.1 Rationale for Price Risk Reduction

Energy efficiency in buildings can be seen as an investment aiming to decrease uncertainty in future heating costs. From a financial point of view an energy efficient building protects the consumer against rising energy costs. Naturally this does nothing to remove any of the risks that are inherently included in any construction investment, for instance those relating to the interest for the capital or the risk that the investment fails to achieve its goals. Nevertheless, a reduction in the consumer’s price risk is an added and commonly overlooked benefit typical to energy efficiency improvements specifically.

People who buy heating energy face the risk of rising energy prices. The standard approach to risky outcomes in economics is the von Neumann-Morgenstern utility function (see e.g. Mas-Colell et al., 1995). The idea is that there are multiple possible outcomes x_i, and for each x_i there is a value $v(x_i)$ that the consumer assigns to them. The sum of all the values v weighted by their likelihood is the value the consumer assigns to the risky undertaking. Let the probability of each x_i be π_i. Then the von Neumann-Morgenstern function for utility u can be stated as follows:

$$u = \sum_{i=1}^{n} \pi_i v(x_i) \tag{1}$$

If energy prices do indeed continue to rise, the payback periods for energy efficiency investments are shortened. After payback, the consumer who invested in an energy efficient building would be accumulating a net profit that would be higher the higher the energy prices. The total cost for heating depending on the initial investment and energy prices can be treated as x_i in Equation (1) and their respective likelihoods as π_i.

The value function v of a typical consumer, shown in Figure 1, is thought to have a concave shape whereby higher levels of consumption provide a diminishing marginal utility. Such consumers will exhibit preference to average outcomes compared to random outcomes. This can be clarified with an example.

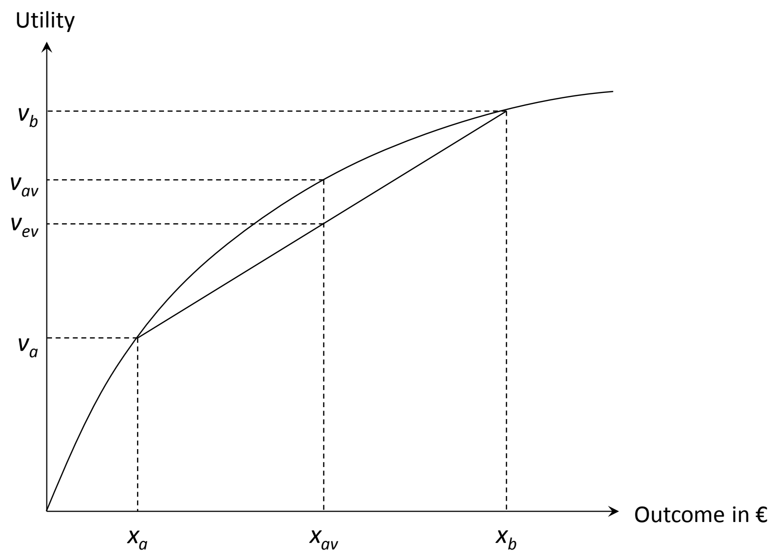

Figure 1: The utility function of a risk-averse consumer.

If the outcomes x_a and x_b in Figure 1 have a 50 % likelihood each and they give the utilities v_a and v_b respectively, then the consumer faces an expected value of utility of v_{ev} which is the average of v_a and v_b. If, however, the consumer can instead choose the average outcome x_{av} with a likelihood of 100 %, then the consumer would receive the utility v_{av}. Since this holds higher utility than v_{ev}, it is preferable compared to the random outcome.

Consumers with such preferences are called risk-averse. This means that the ability to lower the risk holds value to them. Thus the fact that an energy efficient building acts as an insurance against shifts in energy prices provides a premium to risk-averse consumers that does not show in simple investment calculations that concentrate on direct cost savings alone. To include this value of price risk reduction, a wider scope is needed in investment appraisal and a well-founded method to study the said value.

1.2 Review of Price Risk Valuation Methods

In financial economics price risk or market risk is understood as the risk of financial losses caused by movements in market prices (Bank for International Settlements, 2003). The standard approach to price risk management in the energy markets is through the derivatives market where futures and options allow energy buyers and sellers to protect themselves from adverse price fluctuations (James, 2012). The market also allows defining a price for risk reduction by other means, as one has the alternative approach of insuring oneself against price risk using financial products. Any other approach, say an investment to energy efficiency, to reducing price risk makes economic sense only if it costs the same or less than an equivalent financial product in the derivatives market.

The standard approach to derivatives pricing in modern financial theory is the Black–Scholes model. The model is based on the assumption that the prices of traded assets follow a Brownian motion with constant drift and volatility (Profeta et al., 2010). The applications of the Black–Scholes methodology in energy markets concentrates on options trading where the greatest financial interests are at stake (James, 2012). For the purposes of this study an approach that can be used to evaluate the price of price risk reduction in the electricity spot market is needed.

Brennan and Schwartz (1985) approach the problem of valuing uncertain cash flows of an investment project by trying to find a self-financing portfolio of traded securities whose cash flows replicate those which are to be valued. This approach is unsuitable for our case because its output is heavily dependent on market movements and doesn’t produce a stable, simple and practical way of evaluating the value of the investment.

Woo, et al. (2001) offer a practical approach from a seller’s perspective where the seller's risk premium is calculated by asking the following question: "What is the size of the per MWh risk premium that would allow a positive profit over some pre-determined time period with probability P?" While this is a very practical approach from a company's perspective, it doesn't give any concrete estimate for the value of price risk reduction and hence cannot be used here.

Deng and Oren (2006) suggest that due to the unique physical and operational characteristics of electricity production and transmission processes, classical derivative pricing methods based on Geometric Brownian motion, such as the one used in this paper, may not work very well. Instead, they have suggested two alternative approaches. ‘Fundamental approach’ relies on simulation of system and market operation to arrive at market prices while ‘Technical approach’ attempts to model directly the stochastic behavior of market prices from historical data and statistical analysis. Nevertheless, as our goal here is to present how such a calculation could be done in principle, we have chosen to use the most common method in financial industry utilizing geometric Brownian motion suggested by Black. The methods discussed by Deng and Oren (2006) may offer a more well-founded approach in the case of electricity and, thus, offer a clear avenue for further study.

2. METHODS

2.1 Calculating the Value of Price Risk Reduction

The problem of valuating price risk reduction is approached by considering a hypothetical financial instrument that a consumer would purchase to insure herself against unexpected price hikes. A rational consumer is prepared for a certain amount of growth in energy prices. If, however, the energy price rises more than expected, it might be very undesirable for the consumer. The consumer could, at least in theory, prepare for the unexpected rise by buying a cap contract on energy prices which would provide compensation for the unexpected rise. A cap contract bought from the financial markets means that the consumer is guaranteed never having to pay net prices over the agreed cap level. If market prices of energy are higher for a period of time, the consumer only pays a price equal to the cap, the rest being covered by the seller of the cap contract.

The value of a cap contract for the amount of saved energy consumption by an efficiency investment is the value of price risk reduction for the consumer. This is the theoretical fair economical value of the price risk reduction, meaning that in well-functioning financial markets it represents the price of buying capped price security for the same amount of energy consumption that the said energy efficiency investment has allowed to avoid altogether. However, such a cap contract should be viewed as hypothetical, as the practical options for consumers to protect themselves against unexpectedly high energy price rises depend on the market availability of products.

To calculate the value of price risk reduction we use the Black (1976) model for pricing of commodity contacts which is the standard approach used in the financial industry (Zvi et al., 2008). The underlying asset is the Spot price for Nordpool energy price and historical data allows the calculation of volatility in the market. Risk-free interest rate is taken from Euribor yield curve. The expected future prices are estimated based on reasonable energy price inflation expectation, 2.5% for the examples presented here. The strike price for the cap contract depends on the consumer’s personal preference of tolerable energy pricing. For the calculation example we use 40% higher than expected as the tolerance level.

The Black model assumes there are no taxes, margins or transaction costs. This assumption can be used for the calculation of the theoretical fair economical value, but should be borne in mind when interpreting the results as real markets of course entail such costs. Moreover, the Black model assumes that the volatility is constant and that the underlying asset price follows a lognormal distribution. These assumptions may not apply exactly for energy prices, but are nevertheless market practice and selected as a practical approach for the purposes of this paper (Eydeland and Wolyniec, 2003). With these caveats in mind, the cap price can be stated as follows:

$$
\begin{aligned}
C &= NP(0,T)\big(FN(d_1) - KN(d_2)\big) \\
d_1 &= \frac{\ln\left(\frac{F}{K}\right) + \frac{\delta^2 t}{2}}{\delta\sqrt{t}} \\
d_2 &= d_1 - \delta\sqrt{t}
\end{aligned}
\tag{2}
$$

Here C is the price of the cap contract, t is the start time of the contract (years from present), T is the end time of the contract, N is the energy consumption between t and T in kWh, P(0, T) is the value of a T maturity zero-coupon bond at present time, F is the expected price of electricity at time T, K is the maximal tolerated price of electricity at time T (the cap value), N(x) is the cumulative normal distribution function and δ is the annualized electricity price volatility.

To calculate P(0, T) we use the current Euribor yield curve. To calculate δ we use the historical Nord Pool prices for Finland. To make the volatility figure realistic for our purposes, we have used average daily prices of working days and calculated the annualized volatility by multiplying the standard deviation of daily logarithmic returns, meaning logarithm of the quotient of the average prices of two consecutive working days, where Monday is considered as the next day after Friday, with the square root of yearly working days.

2.2 Electricity Price

As volatility is central to our reasoning, the consumer price used for the electricity consumed is based on daily prices in Nord Pool, the Nordic electricity exchange, rather than on long-term fixed-price contracts. Even though the latter contract type is more commonplace, consumers in Finland do have the possibility to buy exchange-priced electricity through a number of power companies.

The price data used for our calculations spans five years from 2007 to 2012 (Nord Pool, 2014). During that period, the average daily spot price in Nord Pool for Finland was 4.34 euro cents per kWh. To this we add, from the same period, the average electricity tax 1.39 c/kWh (Energy Authority, 2014), average VAT 0.97 c/kWh (Nord Pool, 2014), typical power company's price marginal 0.25 c/kWh (e.g. Energiapolar, 2013) and average transmission costs 3.16 c/kWh (Nord Pool, 2014), totaling 10.11 c/kWh to be paid by the consumer. This price is used as the starting level for the price of electricity.

2.3 Case Buildings and Energy Consumptions

The case buildings are variations on a typical Finnish single-family house, which is assumed to be electrically heated with direct electric radiators. This mode of heating remains the most common one in newly constructed single-family houses in Finland (Vilhola and Heljo, 2012). The buildings are assumed to have four dwellers, a typical size for a Finnish family, and to have a net area of 147 m^2 which is likely to be very close to the current average for new buildings. Sizes of new houses have been growing and were reported to be on average 144 m^2 in 2010 (Tiihonen, 2011). The buildings' energetic properties were assumed to follow the 2010 government building regulations (Ministry of the Environment, 2010) and they are assumed to be located in southern Finland.

The different case buildings are as follows:

- Business as usual (BAU), with direct electric radiators as the only source of heat,
- BAU + fireplace, with a fireplace supplementing the radiators,
- BAU + heat pump, with an air source heat pump supplementing the radiators and
- BAU + solar collectors, with roof-mounted solar heat collectors supplementing the radiators.

The building energy and financial calculations were done with the heating energy calculation tool of the Finnish government energy efficiency promotion corporation Motiva (2013). The calculation tool estimates that such a building would consume 4000 kWh/a for domestic water heating and 12230 kWh/a for space heating, totaling 16230 kWh/a. For financing, a 3 % interest rate is assumed, which is typical for a Finnish housing loan (Bank of Finland, 2014). Project lifespan used for financing calculations is set at 20 years.

More details about the various heating systems are given in Table 1. Investment costs as well as energy consumption figures are those given as typical in the Motiva tool. In addition to electricity costs, the firewood is estimated to cost 200 €/a. No other running costs are assumed during the 20 year calculation period or, stated differently, it can be assumed that other running costs of the different alternatives are of similar scale and thus do not affect the calculations. In all the cases the total delivered energy stays the same but the extra investments done in cases other than BAU allow a reduction in the amount of purchased electricity and thus, as the argument goes, also a reduction in the price risk the consumer faces in the electricity markets.

Table 1: Key figures concerning the heating systems in the different cases.

	BAU	**BAU + fireplace**	**BAU + heat pump**	**BAU + solar**
Investment cost (€)	4000	9500	6000	10 000
Electricity consumption (kWh/a)	16387	13984	13488	14370
Other heat sources (kWh/a)	0	2403	2899	2017

3. RESULTS

The results of the investment calculation are shown in Table 2 both in the conventional form, excluding the value of risk reduction, and expanded with the said value. Variable costs are in this case cost of electricity purchasing to the consumer, consisting of the electricity spot price, electricity tax, VAT, power company's price marginal and transmission costs. Capital costs are annualized investment costs from Table 1.

Table 2: Annualized values of selected costs and benefits for the different cases. Benefits appear as a negative cost.

	BAU	**BAU + fireplace**	**BAU + heat pump**	**BAU + solar**
Variable cost	1655	1612	1362	1451
Capital cost	269	639	403	605
Subtotal: cost excl. risk reduction	1924	2251	1765	2056
Value of risk reduction	0	-140	-168	-117
Total: cost incl. risk reduction	1924	2111	1594	1939

The results in Table 2 show that the value of price risk reduction for the various investment alternatives appears to be around 10 % of the total annualized costs: 10 % for BAU + fireplace, 12 % for BAU + heat pump and 8 % for BAU + solar.

4. DISCUSSION

This paper presents a method for calculating the value of price risk reduction to a consumer that can be achieved with investments in energy efficiency. It is based on the Black–Scholes model of pricing. Calculation examples are given for a case building with three investment alternatives for conserving purchased energy and thus reducing the risk of adverse effects from future price changes.

The calculation example demonstrates that a working valuation model for quantifying the value of price risk reduction is possible to construct given the information available from the markets. Based on the calculation the value of price risk reduction is estimated to be around 10 % of the total annualized costs for typical energy efficiency investments in typical single family homes in Finland.

In the case studied the value of price risk reduction is large enough to have an effect on the decision whether to invest. Especially in cases where investments appear marginally profitable, even a benefit of about 10 % can have a pivotal role. Moreover, there are circumstances in which the value of price risk reduction can be higher, such as more volatile markets or investments with smart control of the energy consumption to compensate for fluctuating energy prices.

There is also a methodological issue that means that this value estimate can be somewhat conservative: the Black–Scholes model may underestimate the value of price risk reduction in energy markets because it is based on the use of interest rates from the financial markets as reference, and energy commodities often possess more heavy-tailed price distributions in comparison. Also, as was discussed in the introduction, it is recognized that the Black–Scholes model may harbor other shortcomings for analyses dealing with electricity prices. Thus other potential methodological approaches should be further explored, including the possible tweaking of the Black–Scholes equation. To have a fuller accounting of the benefits of energy efficiency investments, the issue of price risk reduction merits further research.

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